

Magnesium Chloride Empirical Formula Calculation Lab

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Definitions

- I. The reaction: Since there is only one reaction taking place during this lab any reference to “the reaction” relates to $\text{Mg} + 2\text{HCl} \rightarrow \text{MgCl}_2 + \text{H}_2$.
- II. Measure weight: Measure mass of contextual object with digital scale.
- III. Percent comp. : Percent composition.

Introduction

Chemistry is controlled by a set of basic laws that can be used to determine and compile information into usable data. For the following lab the primary law to focus on is the Law of Conservation of Matter, which is critical for understanding why seamless conversions between unit types can be done. For instance, in a single replacement reaction, by measuring the masses of the reactants one can then use this information and dimensional analysis to determine what the composition of the products will be based on their observed mass combined with their studied molar ratios. But this alone is not enough to produce a chemical formula for the product but instead only an empirical formula, the goal for this lab.

Law of Conservation of Matter

The Law of Conservation of Matter is a fundamental concept in understanding the mathematics and physics that exist behind chemical reactions, and consequently, empirical formulas. The Law of Conservation of Matter states that matter can take different forms and can be changed in various ways but can be neither destroyed nor created. Therefore, one can reliably know that the same reactants that are put into a chemical equation will be equal to the products that are yielded. For example in the chemical reaction between Methane and Oxygen $\text{CH}_4 + 2\text{O}_2 \rightarrow 2\text{H}_2\text{O} + \text{CO}_2$, where one can see that every amount of element on either side of the equation are equivalent to each other.

Single Replacement Reactions

Reactions generally come in a standard set of reaction types. These reactions types include reactions from decomposition to synthesis. For the purposes of this lab one will be focusing on the single replacement reaction which follows the pattern of $A + B \rightarrow A + B + N$ where A and B are representative of two metals (exception Hydrogen) and the N represents a non-metal. Metals are substituted for each other during the reaction, hence the name single replacement. The reaction that takes place during this lab is $\text{Mg} + 2\text{HCl} \rightarrow \text{MgCl}_2 + \text{H}_2$. Here the Magnesium replaces the Hydrogen, making the reaction a single replacement. A key part to this reaction is activity, which dictates that Magnesium is more active than Hydrogen, allowing the Hydrogen to be displaced by the Magnesium.

Empirical Formula

A chemical formula is a notation such as C_2H_6 which represents the chemical compound ethane. The difference between these formulas and empirical formulas is that empirical formulas are al-

ways simplified. The chemical formulas on the other hand can be unsimplified. The reason for this is because the chemical formulas only need to follow whole number proportions, without the requirement of being simplified. During this lab, the empirical formula for Hydrogen chloride will be determined due to the method by which quantitative data is collected.

The Mole and Molar Mass

During the lab, the mass of various substances will be collected and this information will be used to determine the empirical formula of Hydrogen chloride. Part of the intermediary process to determining the empirical formula requires the conversion to moles. Moles are a unit of measurement for recording molecules of a compound and represents approximately 6.022×10^{23} molecules. The importance of this unit of measurement is that it has been standardized among most of the elements of the current periodic table. The standardized measurement is a proportion between moles and mass, called a substances molar mass. These values can then be used to accurately make conversions between compounds. For example, an equation such as $\text{CH}_4 + 2 \text{O}_2 \rightarrow 2 \text{H}_2\text{O} + \text{CO}_2$ can be used to relate methane to water. If the mass of methane was provided, the molar mass of methane could be used to retrieve the moles of methane which could then be used to determine the moles of water, and consequently the mass of water.

Mathematics Used in this Lab

Conversion through dimensional analysis:

$$A \text{ gMg} \times \frac{\text{molMg}}{24.31 \text{ gMg}} = B \text{ molMg}$$

Convert grams of Magnesium to moles of Magnesium.

$$F \text{ gCl}_2 \times \frac{\text{molCl}_2}{35.45 \text{ gCl}_2} = G \text{ molCl}_2$$

Convert grams of Chloride to moles of Chloride.

Solving through substitution:

$$D \text{ g}(\text{MgCl}_2 \text{ \& Dish}) = E \text{ gMgCl}_2 + C \text{ gDish}$$

Separate components Magnesium chloride and dish.

$$D \text{ g}(\text{MgCl}_2 \text{ \& Dish}) - C \text{ gDish} = E \text{ gMgCl}_2$$

Use previous equation to solve for grams of Magnesium chloride.

$$E \text{ gMgCl}_2 = A \text{ gMg} + F \text{ gCl}_2$$

Separate components Magnesium and Chloride.

$$E \text{ gMgCl}_2 - A \text{ gMg} = F \text{ gCl}_2$$

Use previous equation to solve for grams of Chloride.

Purpose

The purpose of this lab is to determine the empirical formula of the Magnesium chloride formed by reacting solid Magnesium metal with Hydrochloric acid. This includes adding Hydrochloric acid to solid Magnesium in minute amounts so as to not skew our recorded data of the Magnesium chloride's mass after observing the reaction taking place.

Materials

- Magnesium Ribbon
 - To contribute Magnesium to the chemical reaction.
- Evaporating Dish
 - An area for the reaction to take place and be observed.
- 6M Hydrochloric Acid
 - To contribute Chlorine to the chemical reaction.
- Digital Scales
 - To generate measurements in order to determine the mole ratio of Magnesium chloride.
- Hot Plate
 - To remove most of the excess solution present after the reaction.
- Disposable Pipettes
 - To transfer Hydrochloric acid from its original container into the evaporating dish.
- Tongs
 - To place and remove the evaporating dish from the hot plate.
- Safety Goggles
 - To protect your eyes from general lab accidents.
- Data Table
 - To store records of the masses and moles of substances during points in the reaction.
- Writing Utensil
 - To write measurements of masses and moles onto the data table.
- Procedure Guide
 - To provide instruction and focus during the execution of the lab.

Procedure

1. Put on safety goggles.
2. Turn on digital scale and zero out.
3. Retrieve piece of Magnesium ribbon.
 1. Measure weight, and record.
4. Retrieve evaporating dish.
 1. Measure weight, and record.
5. Place Magnesium ribbon on evaporating dish.
6. Retrieve Hydrochloric acid.
 1. Slowly use pipette to transfer drops of Hydrochloric acid onto Magnesium ribbon waiting in between drops until the ribbon has been fully dissolved. (Keep head away from yielded gases)
7. Turn on the hotplate to level seven.
 1. Continue to keep head away from vaporizing gases.
8. Wait until all excess solution has vaporized.
9. Use tongs to remove the evaporating dish from the hot plate.
10. Wait until products have cooled down to approximately room temperature.
 1. Measure weight, and record.
11. Convert every mass measurement on data table into its corresponding mole value.

Lab Results

Key Values: Values Collected and Produced

(A)	0.13g	Mass of Magnesium ribbon
(B)	5.348mol	Mole of Magnesium
(C)	26.95g	Mass of empty evaporating dish
(D)	27.42g	Mass of Magnesium chloride and evaporating dish
(E)	0.47g	Mass of Magnesium chloride
(F)	0.34g	Mass of Chloride
(G)	9.591mol	Moles of Chlorine
(H)	{1:2}	Ratio of moles of Magnesium to moles of Chlorine

Qualitative Data

Materials

Before the lab began the materials were inspected. The Magnesium ribbon was silvery, gray and had anisotropic reflective properties. The evaporating dish appeared to be ceramic, fired/glazed, and white/cream colored. The hydrochloric acid was transparent and colorless.

Reaction

When the two reactants (Magnesium and Hydrochloric acid) were combined in the evaporating dish, they became part of a chemical reaction. The reaction generated white bubbles while the solution slowly became clouded. The Magnesium ribbon broke several times before completely dissolving into the solution. Over time, the volume of the solution reduced.

Hot Plate

Once the reaction was finished and the remaining solution was moved onto the hot plate, the solution began vaporizing. The gas that elevated from the evaporating dish was clear and white. After several seconds, the solution began boiling. The solution boiled until all liquid was vaporized, at which point only a white powdery substance remained in the evaporating dish.

Analysis

Calculation of Results

The mathematics behind retrieving the key values is above and can be used by substituting the standing variables with the measured values from the lab.

(A) 0.13g

(C) 26.95g

(D) 27.42g

Take the measured value for Magnesium mass and convert it to moles using dimensional analysis:

$$0.13 \text{ gMg} \times \frac{\text{molMg}}{24.31 \text{ gMg}} \approx 5.348 \text{ molMg} \quad (\text{A}) \rightarrow (\text{B})$$

Isolate the mass of Magnesium chloride from itself and the evaporating dish using the substitution principle:

$$27.42 \text{ g}(\text{MgCl}_2 \& \text{ Dish}) - 26.95 \text{ gDish} \approx 0.47 \text{ gMgCl}_2 \quad (\text{C}, \text{D}) \rightarrow (\text{E})$$

Isolate the mass of Chloride from Magnesium chloride using the substitution principle:

$$0.47 \text{ gMgCl}_2 - 0.13 \text{ gMg} \approx 0.34 \text{ gCl}_2 \quad (\text{A}, \text{E}) \rightarrow (\text{F})$$

Take the produced value for mass of Chloride and convert it to moles of Chloride using dimensional analysis:

$$0.34 \text{ gCl}_2 \times \frac{\text{molCl}_2}{35.45 \text{ gCl}_2} \approx 9.591 \text{ molCl}_2 \quad (\text{F}) \rightarrow (\text{G})$$

Finally compare moles of Magnesium to moles of Chloride using simplification and approximation:

$$\{5.348 \text{ molMg} : 9.591 \text{ molCl}_2\} \approx \{1:2\} \quad (\text{B}, \text{G}) \rightarrow (\text{H})$$

Comparison

Using a combination of dimensional analysis and substitution principle, one is able to produce the empirical formula of Magnesium chloride through observation and measurement of the reaction between Magnesium and Hydrochloric acid. Using the percent error formula and the percent composition of Magnesium to Magnesium chloride one can determine the overall accuracy of the measurements and the lab:

$$\left| \frac{0.13}{0.47} \right| \cdot 100 \approx 27.66\% \quad \text{Percent comp. of Magnesium from lab measurements}$$

$$\left| \frac{27.66 - 25.5}{25.5} \right| \cdot 100 \approx 8.47\% \quad \text{Percent error from lab measurements}$$

Conclusion

By completing this lab one found that the empirical formula of Magnesium chloride is MgCl_2 . By checking the empirical formula of Magnesium chloride against the IUPAC resources^[7], one can verify that the lab measurements yielded accurate results. This lab has determined that using only three measurements: (A, C, D), it is possible to yield the empirical formula of Magnesium chloride.

The results yielded by the calculations described above in sections [Introduction: Mathematics Used in this Lab] and [Analysis: Calculation of Results] are proven to be accurate within 10% which is of enough precision by Mr. Kim's standards to qualify as accurate. Therefore, one can conclude that the lab was evaluated correctly and without major complications.

It is always necessary to shed light on the inaccuracies if any that exist in lab data. In this lab, the largest inaccuracy was likely generated by a lack of measuring precision. One could notice that the scales were continually changing values, an entropy that could be attributed not to their calibration, but to other, difficult to discern variables such as convection currents generated by unequal temperatures in the room, or air conditioning systems applying extra pressure onto the surface of the scale. All of these can contribute to inaccurate measurements. The second most likely source of error would come from an inability to observe when the precise amount of Hydrochloric acid has been contributed to the reaction, before it has become an excess reactant, causing the mass measurements of the Magnesium chloride in the evaporating dish to be thrown off.

Due to the ability of being performed and conducted accurately, the real life applications of this lab can be primarily attributed to the mathematics portion, where converting between units and breaking down measurements into more useful components can be beneficial for value gathering. For example, if one has a solution that consists of salt dissolved in water, they can determine an equation for describing the relationship between the mass of the salt to the mass of the water:

$A \text{ gTotal} = B \text{ gWater} + C \text{ gSalt}$ which can be rewritten as $A \text{ gTotal} - B \text{ gWater} = C \text{ gSalt}$ in order to find the original mass of the salt if the mass of the water is given.

Citations

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